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Small-Scale Experiments in Plasma-Propellant Interactions

by Richard A. Beyer

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Small-Scale Experiments in Plasma-Propellant Interactions

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Abstract

A series of experiments has been performed to continue the process of characterizing the interaction between a hot plasma igniter such as is in use in electrothermal chemical (ETC) guns, and a variety of gun propellants. The primary diagnostic in the research reported here is pressure generation records for different interaction geometries. It is found that ignition times may be shorter for propellants with weaker optical absorption, such as M9 or JA2, than those with stronger interaction with the plasma, such as M30. This difference is attributed to the ablation of the surface without significant energy transfer to the bulk of the material in the latter case.

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1. Introduction

The U.S. Army research community has been moving swiftly to reorient itself to provide the technology required to provide the target levels of mobility, lethality, and survivability for the objective force. One element of this force is the Future Combat System (FCS), formerly known as the Future Combat Vehicle (FCV). If the FCS is to be armed with a high-performance cannon within the expected weight and volume restrictions, advances will be necessary in gun performance. One of the promising cannon candidates is a design with a high-density charge of a next-generation propellant ignited by an electrothermal plasma, referred to as electrothermal chemical (ETC). The charge will be designed physically and chemically to have optimized ignition characteristics for plasma ignition while maintaining relative insensitivity to threat stimuli. These propellants are part of the category of insensitive high-energy materials (IHEM).

The key to designing a propellant charge that is "plasma specific" is a detailed understanding of the mechanism of propellant ignition by a plasma. The plasmas used in these systems are typically started by an exploding wire. The wire creates a conductive plasma which is then sustained for the duration of the electrical pulse by ablation of small amounts of material from the adjacent wall, which may be either a polymer such as polyethylene or part of the propelling charge. The resulting plasma then flows into the propellant bed at high velocity, where it has been shown by gun tests [1] to be an extremely robust and prompt igniter. From these experiences, it is considered possible that a plasma igniter can effectively ignite a high-density charge of relatively insensitive propellant. This research is a portion of an ongoing effort to determine the mechanism by which the plasma so effectively ignites propellant.

The plasma has several properties that may be important. The temperature of the plasma [2] as it exits the capillary has been measured at above 10,000 K. In shock waves, the gases may exceed 50,000 K. Thus, there is an abundance of emitted radiation which goes far into the ultraviolet. Possible effects of this radiation vary from photochemical changes within the propellant structure (ultraviolet) to in-depth heating of relatively transparent propellants (visible and infrared). The composition of the plasma is a mix of highly reactive ions and neutrals that can attack propellant surfaces and ignite or predispose them for ignition. The flow has a high velocity which enhances convective heat transfer. In addition, our studies have shown that the flow may include a high number of very small particles that may enhance energy transfer and ignition. The goal of the present research is to separate these properties, identify their impact, and guide the development of propellant properties to tailor ignition behavior.

In this project, the approach was to develop a relatively small-scale apparatus for the study of plasma-propellant interactions which will allow a large number of experiments. Unlike gun-scale experiments, which can be done a few per day, these measurements can be repeated relatively rapidly. This approach allows better determination of the range of variability of effects rather than the extreme detailing of one experiment as is sometimes done at present. The first series of experiments is underway using a capillary plasma generator in which approximately 600 J of energy is deposited. Detailed spectroscopic measurements had been done earlier to characterize the plasma temperature as it exits the capillary and forms shock waves in open-air experiments. Although the physical size and total energy deposited into the plasma are much smaller than would be required for a gun igniter, the physical and chemical environment has been shown to duplicate that of a gun system in the small volume where the tests are performed.

In addition to observing the response of propellants to a plasma these experiments can be terminated by depressurization to provide propellant samples for chemical analysis. By using analytical chemical techniques to profile key indicators through these samples, evidence of modification of the sub-surface composition can be obtained. Reference [3] details some of these measurements and their interpretation.

2. Experimental Description

The heart of these experiments is a polyethylene capillary with a 3-mm-diameter bore and 35-mm length. It is mounted in a steel case for structural support and insulated electrically. A schematic diagram is shown in Figure 1. A fine aluminum wire (0.1-mm diameter) is initially present between the two electrodes. The device is powered by a capacitor bank with about 675 J of stored energy and pulse-forming network that delivers the energy to the circuit in about 300 μs. At the beginning of the current flow, the wire explodes and forms an ionized (electrically conducting) region in the capillary. As the current flows through the capillary, ohmic heating deposits energy onto the wall, which then ablates, decomposes rapidly, and feeds the plasma to maintain the conductivity.

In a typical event, 570 J are deposited into the plasma discharge. The materials active in the discharge are the wire (4 mg), the capillary wall (25-mg typical mass loss), and material eroded from the electrode surface. During the discharge, the current and voltage of the plasma are measured; from these values the power and energy deposited are calculated. A typical set of electrical curves is shown in Figure 2.

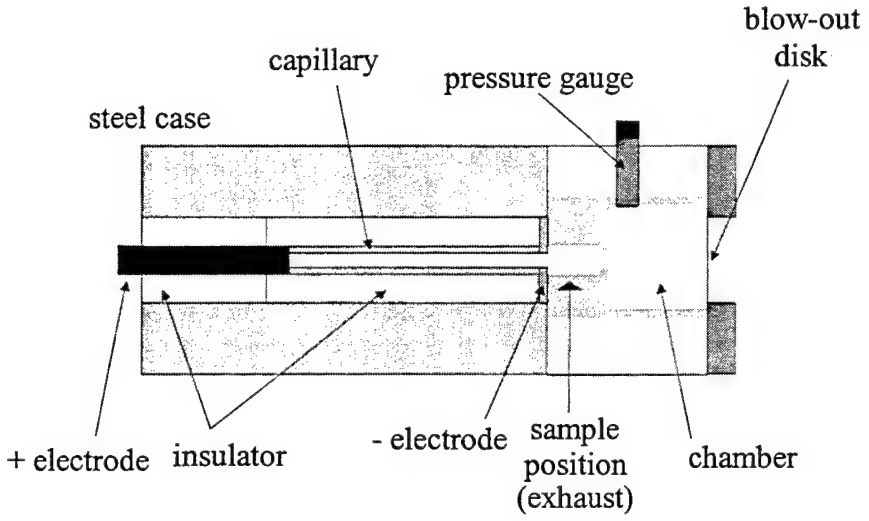

Figure 1. Schematic diagram of capillary discharge plasma generator and attached chamber.

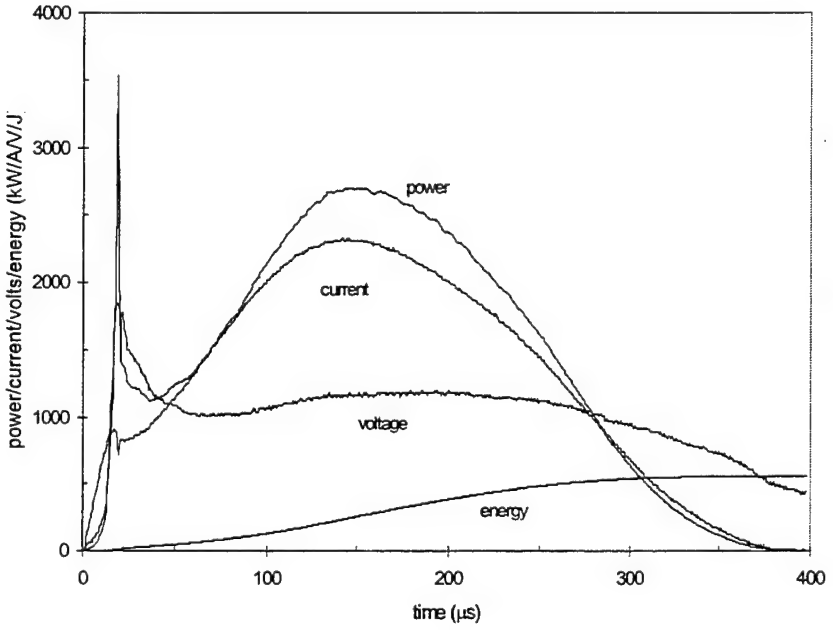

Figure 2. Typical electrical curves for plasma discharge through device in Figure 1.

Also shown in Figure 1 is the propellant interaction chamber of the apparatus. For observations reported here, propellant grains have been mounted either in the direct exhaust from the capillary (as a single-perforation grain with the plasma vented through the grain) or in the chamber. The former method provides a strong interaction with maximum convective interaction; the latter

allows the plasma to expand, cool, and possibly decrease the relative velocity. Total volume of the chamber is 2.3 cm [3]. Various rupture disks are used to terminate the experiments as desired from near the pressure generated by the plasma only up to the operational limit of the device (8,000 psi/55 MPa).

With the plasma entering a closed chamber, an important issue is the effect of chamber pressure on the internal working of the capillary. The fundamental behavior of this type of capillary discharge has been modeled [4] and extended to materials other than polyethylene [5]. In addition to the fundamental physical properties of the capillary, this model accepts the discharge current and external pressure and from them calculates the internal pressure. This code allows confirmation that the external conditions are probably influencing the discharge. As can be seen from the calculated internal pressure in Figure 3, it does not require an extreme external pressure for the interior parameters to be influenced. This modeling of other capillary materials will provide part of the basis for future studies of modified plasma composition.

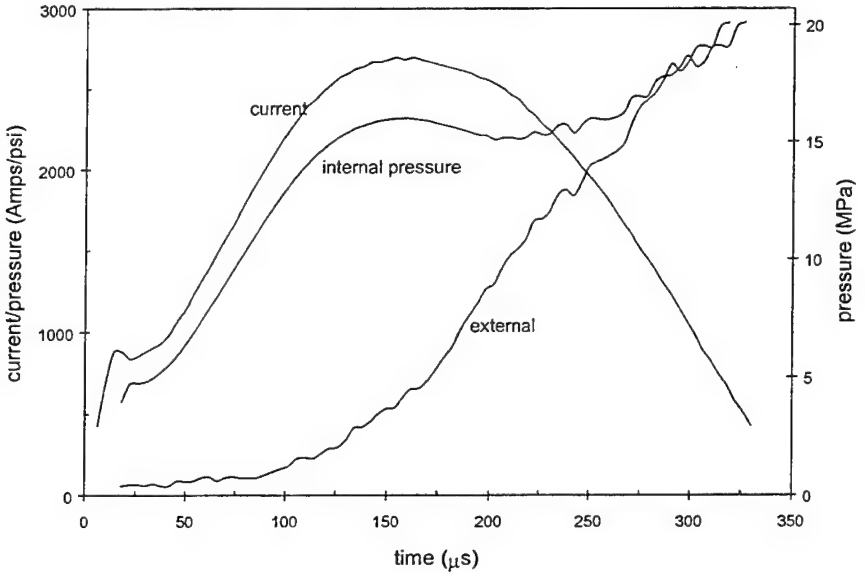

Figure 3. Pressure calculated in capillary from current and external measurements. Note that a relatively low external pressure is required to eliminate critical flow from the orifice and affect the internal behavior.

3. Propellants Evaluated

Three standard gun propellants were used in most of these experiments. They were chosen for both their differences in physical characteristics and because of

different behavior in previous ETC plasma-propellant experiments [6]. They are M9, a hot double-base propellant (nitrocellulose [NC] with a nitroglycerine [NG] plasticizer); JA2, a modified double-base propellant (NC with NG and diethylene glycol dinitrate [DEGDN] plasticizers); and M30, a high performance triple-base propellant (NC, NG, and nitroguanidine [NQ]). The M9 was chosen because of its high transparency to visible and infrared radiation from the plasma; M30 also has relatively low absorption in this region. JA2 has added graphite in its composition which results in moderate absorption at wavelengths longer than 500 nm and strong absorption at shorter values. Of these three propellants, the M9 has the most mechanical resilience at ambient temperature, where all observations were recorded, and the M30 is the hardest. A limited number of experiments were done with a thermoplastic elastomer (TPE) propellant, TDG-009, which is a fairly soft material (at ambient) with a cyclotrimethylenetrinitramine (RDX) fill. Except as noted, the propellant was used as 6.3-mm (0.25-in) diameter grains with a single 3.2-mm (0.125-in) perforation. Typical sample size was near 250 mg. Fraction of sample consumed varied from 25% to 100%.

4. Observations

Three types of interactions were used in attempts to characterize the plasma effect on these propellants. The first method was to mount a flat sample of JA2 at the exit of the capillary in open air, without the chamber section attached. The second setup was to mount a single grain at the exhaust of the capillary so that the plasma discharges from the capillary through the center perforation. The third method used was to insert the single grain into the chamber. In the last two methods, pressure was the principal real-time diagnostic.

Placing a flat propellant sample at the capillary exit in open air (with no chamber present) provides a fairly short exposure to the initial high-velocity plasma gases, followed by a rarefaction wave, and then the flow of the core gases onto the propellant surface. While the fluid dynamics is complex [7] this approach yields a sample of propellant that has been exposed to a significant quantity of the light, solid particles, and flow from the plasma core. The result is typically a region of interaction that mirrors the size of the capillary orifice and which suggests subsurface gas-generating reactions. A photograph of the result of one of these experiments is shown in Figure 4. The strongly affected area has a diameter of about 8 mm.

In order to explore the interaction of plasma with propellant where actual ignition of the propellant is achieved, the closed-chamber techniques were pursued. The sample mounted at the capillary exhaust provides a highly dynamic flow with strong contact between the plasma and the sample. The

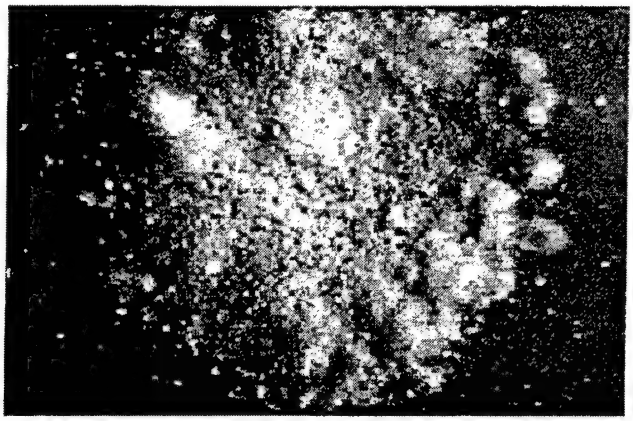

Figure 4. Photograph of JA2 sheet propellant placed in exit flow from capillary normal to flow.

location of the sample in the chamber is still a very aggressive environment for ignition, but the plasma has traveled through the small exit region and mixed with the ambient air which both cools and dilutes it.

The behavior of the propellants is clearly divided into that during the plasma event and that which follows. Figure 5 shows smoothed pressure-time traces for the four types of propellants mounted in the plasma exhaust. The pressure is measured in the chamber. The plasma duration is similar to that seen in Figures 2 and 3 and is fully discharged by 350 μs.

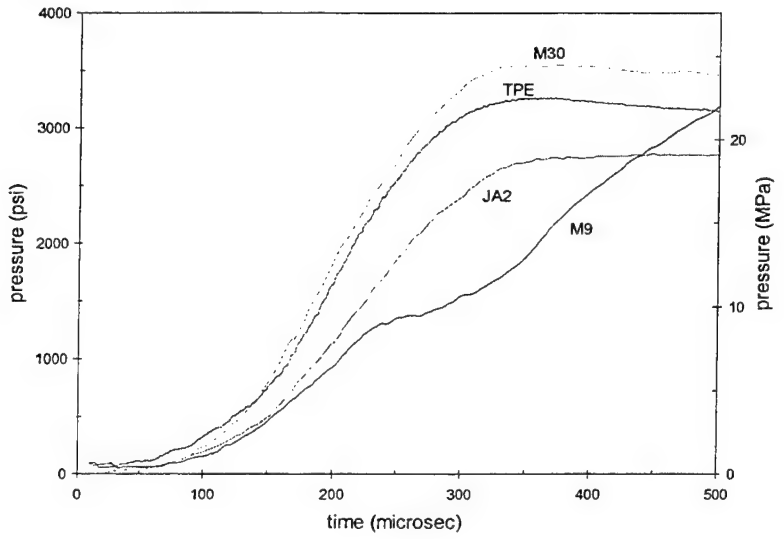

Figure 5. Chamber pressure records from various propellants in plasma exhaust during time that plasma discharge is on.

As suggested in the figure, M30 consistently yields a boost in pressure well above that of the plasma alone. The TGD-009 has a slight increase in the rate of pressurization but typically is only slightly above the plasma alone. During the time that the plasma is on, M9 is below the pressure generated without propellant. JA2 in the exhaust position usually results in a pressure rise above that of plasma only, but the amount of increase is not consistent. These two (JA2 and M9) are also the quickest to proceed to full ignition and event termination. Figure 6 shows the remainder of the event when more complete combustion is allowed. As can be seen, M9 and JA2 are ignited promptly. M30 and the TPE have clear ignition delays during which the pressure drops due to heat loss to the walls. This same order of pressurization is observed for samples placed in the chamber, where the ignition stimulus and flow velocities are considerably reduced.

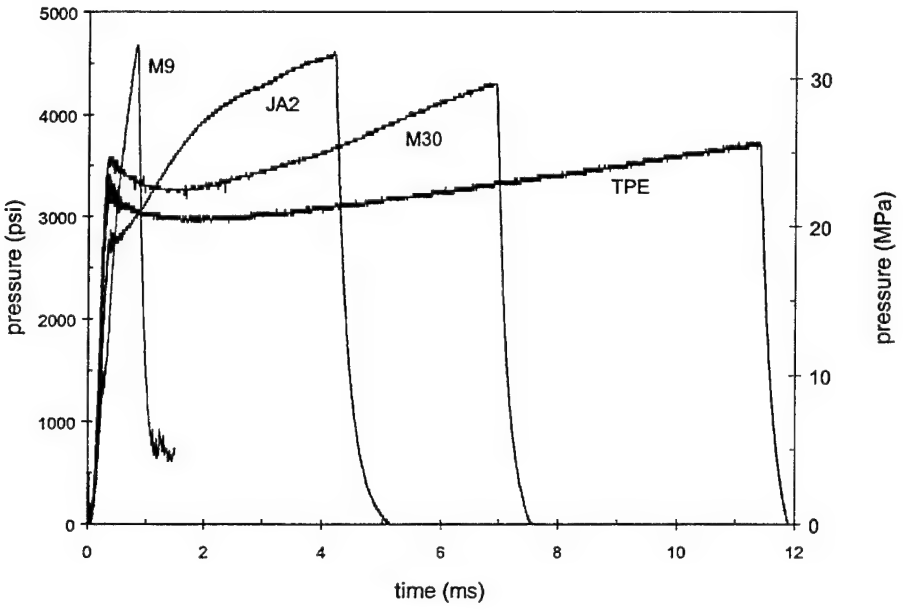

Figure 6. Pressure records for times after plasma discharge for propellants in plasma exhaust.

Because of the decrease in pressure in the chamber when the plasma is vented through the M9 sample, it is interesting to compare the pressurization in that configuration with that of a similar sample in the chamber. In Figure 7, the point where the pressure appears to drop below the plasma-only pressure is noted as "break." Calculations are presently being attempted to determine if these data are sufficient to tell how much of the M9 sample must break up, i.e., what the surface area must be, to generate this pressurization curve.

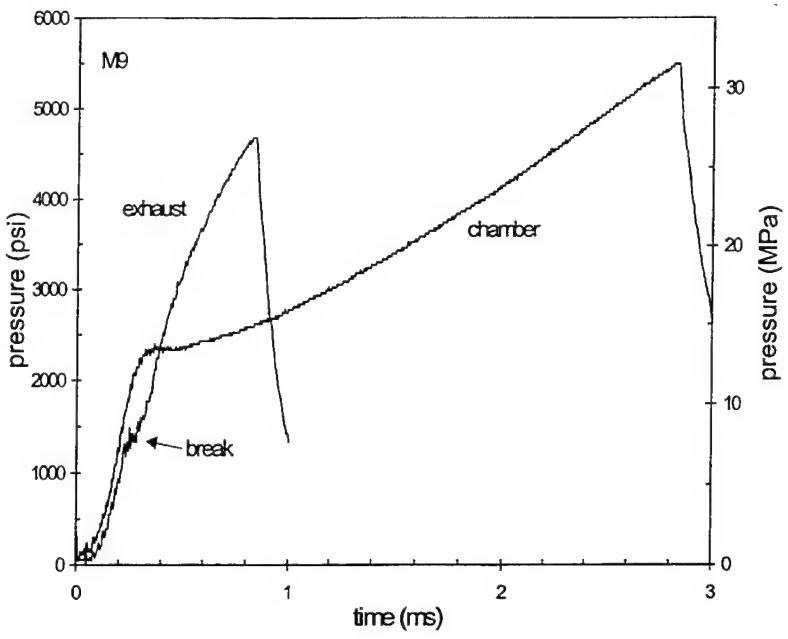

Figure 7. Comparison of M9 propellant pressure records for plasma interaction by direct exhaust through the center perf and with sample mounted in chamber.

The effect on pressure during the plasma discharge due to JA2 is less clear and not as reproducible. However a comparison of the two configurations indicates that the JA2 is burning with increased surface area (or modified burning rate) for a period of time after the plasma is terminated. This is shown in Figure 8. If the propellant were burning normally, the "exhaust" curve would have a slope similar to that of the "chamber" curve. JA2 samples, which were exposed to the plasma and quenched near the end of the discharge, were examined and found to have a "lacy" surface with clearly modified surface area. A photograph of the inner section of a recovered grain is shown in Figure 9. JA2 is the only material that showed this behavior. However, the response of M9 to the plasma was so strong that samples were not recovered following direct plasma interaction.

A similar comparison of the pressurization behavior with M30 in the two positions is shown in Figure 10. As can been seen in this figure, the ignition in both cases is quite similar. The pressure from events during the plasma discharge is decreasing when the propellant ignites with the resulting pressure rise. The TGD-009 show similar behavior on a somewhat longer time scale.

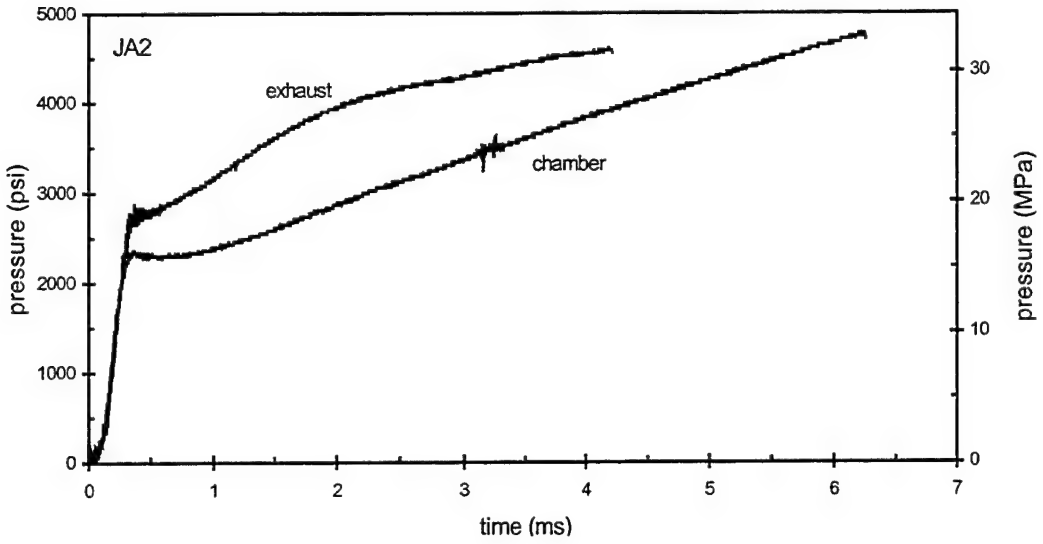

Figure 8. Comparison of JA2 propellant pressure records for plasma interaction by direct exhaust through the perforation and with sample mounted in chamber.

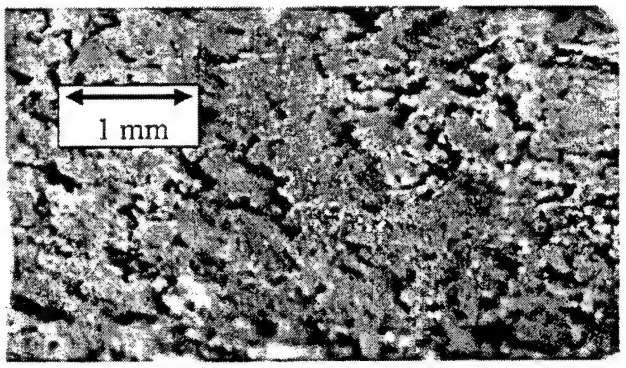

Figure 9. Photograph of JA2 sample mounted in the plasma exhaust and quenched near end of plasma exposure.

In order to provide samples for chemical analysis [3] and microscopic observation, a limited number of experiments were performed with the burst disk designed to rupture shortly after the end of the plasma pulse. These were performed with the plasma venting directly through the single perf ("exhaust configuration"). In one trial with M30, the mass of the sample was reduced from 256 to 243 mg during the plasma exposure. The interior surface of this grain was very smooth. A simple geometric calculation yields a change in radius of the perf of 0.13 mm, which is consistent with the measured values in the companion analysis paper [3]. A simple calculation of the expected pressure rise from complete combustion of the missing propellant yields 900 psi (6 MPa), which is comparable to the observed pressure rise.

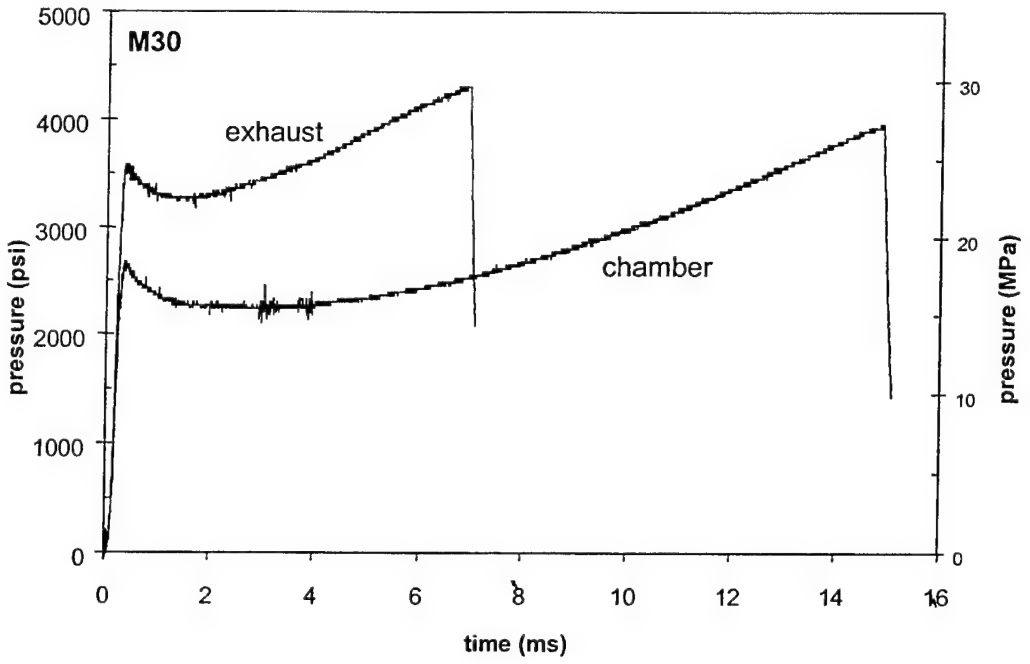

Figure 10. Comparison of M30 propellant pressure records for plasma interaction by direct exhaust through the perforation and with sample mounted in chamber.

A similar experiment with a JA2 grain showed a change from 254 to 180 mg. This sample is pictured in Figure 9. In spite of the appearance, a simple geometric calculation can be done to show that this mass loss corresponds to an increase of the radius of about 0.6 mm. This is greater than measured [3]. An impetus calculation for the mass change yields a pressure rise of 5,000 psi (30 MPa), much greater than the observed value.

5. Discussion

The pressure rise in the chamber resulting from the exhaust of the plasma through the center of a propellant grain, as shown in Figure 5, is a strong indicator of the response of each material. It is clear in these experiments that M30 always yields a significant boost in pressure, probably indicating full release of the chemical energy of the affected propellant volume. The JA2 samples, which show an increase in surface area from plasma erosion, generally are only slightly above the pressure from the plasma alone during the plasma pulse. They show a much greater missing volume of propellant but much less chemical energy release. Thus it is concluded that much of the erosion of the surface of JA2, as shown in Figure 9, for example, is from processes which are removing

"chunks" of material with very incomplete chemical reaction. It is not possible to discern from these observations whether the generation of pressure from the M30 is caused by removal of surface material in small particle size (fracture), which quickly burn away from the surface, or if the energy release is better characterized as radiation- or plasma-assisted burning at the surface. The mechanism for this removal can be thermal-mechanical shock from rapid heat transfer (convective or radiative) or chemical interaction between the highly ionized plasma flow with the surface or perhaps radiation-assisted combustion of the surface.

There has been speculation in the ETC community [8] about the "gasification" of propellant by the plasma as one explanation of observed gun-ignition phenomena. The present observations, though on a small scale, demonstrate that there is a fast release of the chemical energy during the plasma discharge for propellant M30, and to a lesser extent, the TPE, and even less for JA2. For others, such as M9, the propellant appears to respond by breakup into particles sufficiently large to slow the flow through the orifice between the propellant grain and the pressure sensor in the chamber. The source of this apparent breakup would appear to be related to in-depth absorption of the plasma radiation, but further experiments are needed to demonstrate this conclusively. Ideal experiments with propellants which are identical except for optical absorption characteristics are presently being planned to address this question.

The ignition delay and pressurization behavior of the M30 following the plasma pulse is consistent with a sample left almost in a virginal state following plasma exposure, perhaps with a slight temperature increase. The JA2 transitions to ignition much more rapidly than the M30. These apparently conflicting indications are discussed in a paper on chemical analysis of these samples [3]. In that paper are presented arguments that the heat transfer to the M30 is relatively small since all portions of the sample, which interact with the plasma, are ablated. In contrast, the JA2 (and possibly M9) have significant energy deposited far enough below the surface to ignite the sample in a sustained fashion. This interpretation is consistent with earlier observations by Kaste et al. [9] in comparing the relative color of plasma- and conventional-ignited M30 grains. In that work, the plasma-exposed grains showed less color change, which is usually indicative of combustion.

The original choice of these propellants was based both on availability and optical characteristics from earlier measurements [10]. In particular, M9 was chosen because it is much more transparent in the visible and near infrared regions. Thus it was predicted that we could compare the bulk energy deposition of M9 to the more localized near-surface energy absorption of the JA2. Surface absorption usually means a high local temperature (and prompt ignition), whereas bulk absorption may result in a total temperature rise of only a few degrees [10]. However, the chemical analysis shows clearly that the higher

absorption measured for JA2 is probably due to the graphite. Because it is not uniformly dispersed and particle size is comparatively large, the actual absorption is in a relatively few "hot spots" under the surface. These locations appear to provide gas generation sites, which cause near-surface breakup into particles that are too large to be quickly consumed during the plasma [3]. In this respect, JA2 is more like M9 in that it breaks up during the plasma; the difference seems to be that the M9 ignition and combustion following this delay are much more rapid. This difference is probably tied to the chemical differences of the two propellants.

While trying to draw conclusions and discern patterns in these limited experiments, it is important to remember that the energy required for ignition and the subsequent gas generation rates at these pressures varies greatly among these propellants. Understanding of these characteristics may be more nearly achieved with propellant samples with tailored optical absorption coefficients. There may also be a difference in absorption as measured with an analytical instrument in the laboratory and the absorption of a propellant while exposed to the spectrum of a typical ETC plasma. While not discussed here, many mechanisms could be proposed for greatly enhanced absorption during the event.

6. Summary

The key conclusions made from the observations discussed in this report are the following:

- The interaction of M30 propellant with the plasma is sufficiently shallow at the surface that an ablative process occurs with little heat transfer to the remaining material. In spite of rapid gas generation and energy release from the affected material, ignition delays for the bulk are observed.
- The interaction of JA2 and M9 with the plasma result in removal of large amounts of material with relatively little energy release or gasification. Surface area is enhanced and affects behavior of JA2 following the plasma, as seen in Figure 7. There appears to be more heat transfer to the bulk of these propellants than with M30.
- Samples of propellants with well-controlled optical absorption characteristics are needed to unscramble the multiple processes in the plasma-propellant interactions.

7. Future Work

Efforts are required on several tasks to obtain clear evidence to separate the various possible interactions between the plasma and various propellants. The first is to obtain propellant samples that have optical absorption coefficients designed to control the deposition of energy from various wavelengths of the plasma where the propellant is otherwise transparent. Deep ultraviolet, for example, which may be extremely important because of its abundance and possibility of photochemical initiation of reactions, is expected to be strongly absorbed near the surface of most materials.

Better characterization of the fine (submicron) particles present in the flow and their role in plasma ignition may be important. These particles are extremely penetrating and may contribute to ignition in a manner different from the usual macroscopic particles of a conventional ignition system. It has been observed that modifying the chemical composition of the plasma through capillary changes can affect the quantity of particles as well as changing the chemical composition of the flow which interacts with the propellant.

In addition to these laboratory observations, closer coordination with the effort to model the fluid dynamics and gas-phase chemistry of the flow [7] is anticipated both for future experimental design and analysis.

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8. References

1. Katulka, G., and J. A. Dyvic. "Experimental Results of Electrical Plasma Ignition in 120-mm Solid Propellant Tank Gun Firings." *The 33rd JANNAF Combustion Meeting*, CPIA Publication 653, vol. III, pp. 103–110, November 1996.

2. Beyer, R. A., and S. W. Bunte. "Spatial and Temporal Temperature Studies of Electrothermal Chemical (ETC) Plasmas." BRL-TR-3324, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, March 1992.

3. Pesce-Rodriguez, R. A., A. E. Kinkennon, R. A. Beyer, M. Del Güercio, P. J. Kaste, and J. E. Newberry. "In-Depth Chemistry in Plasma-Exposed M30 and JA2 Gun Propellants." ARL-TR-2505, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, June 2001.

4. Powell, J. D., and Z. E. Zielinski. "Theory and Experiment for an Ablating-Capillary Discharge and Application to Electrothermal-Chemical Guns." BRL-TR-3355, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, July 1992.

5. McQuaid, M. J. "Characterization of the Discharge From and Ablating-Capillary Arc Ignition System Equipped With a Poly (Ethylene Terephthalate) Liner." ARL-TR-2260, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, July 2000.

6. Del Güercio, M. "Propellant Burn Rate Modification by Plasma Injection." ARL-TR-1801, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, September 1998.

7. Nusca, M., M. J. McQuaid, and W. R. Anderson. "Development and Validation of a Multi-Species Reacting Flow Model for the Plasma Jet Generated by an ETC Igniter." *The 37th JANNAF Combustion Meeting*, CPIA Publication no. 701, vol. I, pp. 181–199, November 2000.

8. Su, F. Y. "Recent 120-mm ETC Data Analyses and Propellant Gasification Hypothesis." *The 36th JANNAF Combustion Meeting*, CPIA Publication no. 691, vol. III, pp. 83–94, October 1999.

9. Kaste, P. J., A. E. Kinkennon, R. A. Pesce-Rodriguez, M. A. Del Güercio, D. D. Devynck, A. Birk, S. L. Howard, and M. A. Schroeder. "Chemical Analysis of Extinguished Solid Propellants From an Interrupted Closed Bomb With Plasma Igniter." *The 35th JANNAF Combustion Meeting*, CPIA Publication no. 680, vol. II, pp. 279–291, October 1998.

10. Williams, A. W., and K. J. White. "Plasma-Propellant Interaction Studies: Measurements of In-Depth Propellant Heating by Plasma Radiation: Investigation of Possible Plasma-Induced Propellant Erosion." *The 36th JANNAF Combustion Meeting*, CPIA Publication no. 691, vol. II, pp 67–76, October 1999.

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13. ABSTRACT*(Maximum 200 words)*

A series of experiments has been performed to continue the process of characterizing the interaction between a hot plasma igniter such as is in use in electrothermal chemical (ETC) guns, and a variety of gun propellants. The primary diagnostic in the research reported here is pressure generation records for different interaction geometries. It is found that ignition times may be shorter for propellants with weaker optical absorption, such as M9 or JA2, than those with stronger interaction with the plasma, such as M30. This difference is attributed to the ablation of the surface without significant energy transfer to the bulk of the material in the latter case.

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